

$$\begin{aligned} \text{Quick displacement} &= \begin{cases} 0.016 \text{ mm., downwards.} \\ 0.014 \text{ ,, towards the N. } 51^\circ \text{ E.} \end{cases} \\ \text{Slow ,,} &= \begin{cases} 0.051 \text{ ,, ,, N. } 51\frac{1}{2}^\circ \text{ E.} \\ 0.054 \text{ ,, downwards.} \end{cases} \end{aligned}$$

The earthquake origin seems to have been situated 11 km. to the N.  $51^\circ$  E. of the Yuno-taira observatory, i.e., at the N.E. base of the mountain, about  $\varphi=36^\circ 27'.4$  N.,  $\lambda=138^\circ 35'.4$  E.

**83. Summary of results.** The elements of motion of the different non-eruptive volcanic earthquakes described in the preceding §§ are collected in Table XXV. It will be noted that the volcanic earthquakes took place at varying radial distances from the Asama-yama crater. Amongst the others, the strong shock on July 16th, 1912, and five of the earthquakes in 1917 took place at the radial distances less than 6 km., mostly from the region lying to the S. of the present Asama-yama crater.

## CHAPTER IX. NON-ERUPTIVE ASAMA-YAMA EARTHQUAKES OBSERVED IN TOKYO.

**84. Observation in Tokyo.** In §§ 85–90 I give notes on the tromometer observations\* at the Seismological Institute (Tokyo) of the following five strongest recent Asama-yama volcanic earthquakes:—

- |                        |                                   |
|------------------------|-----------------------------------|
| (1) May 26th, 1908.    | (3) Jan. 22nd, 1910.              |
| (2) July 16th, 1912.   | (4) April 2nd, 1911.              |
| (i) Jan. 22nd, 1899.** | (5) Aug. 17th, 1912. (Ueda Eqke.) |

(i) and (ii), which were the most violent Asama-yama earthquakes so far experienced, gave identical registers in Tokyo. The seismograms are reproduced in figs. 36 and 38–42.

\* 2a denotes the double amplitude, and T the complete period of vibration.

\*\* (i), which is not an earthquake of the Asama-yama origin, is given for the sake of comparison (See § 100)

**85. (1) *Earthquake of May 26th, 1908.*** (See § 99.) Time of commencement=9.08.00 a.m. Duration of the preliminary tremor=18.5 sec. Total duration=20 min. [E.W. Component.] In the principal portion, whose duration was  $4^m 15^s$ , the motion was small during the first 21 sec. and consisted of the vibrations of  $T=5.9$  sec., max.  $2a=0.5$  mm. Then the motion became large and consisted of regular vibrations of  $T=7.3$  sec., of which the two maximum vibrations of  $2a=1.8$  mm. and of  $2a=1.9$  mm. took place respectively 47 and 68 sec. after the commencement of the earthquake. A second conspicuous maximum group which occurred at the end of the epoch under consideration, and lasted 46.4 sec., began  $3^m 35^s.4$  after the earthquake commencement and was composed of 8 regular vibrations of  $T=5.8$  sec., and of max.  $2a=1.5$  mm. In the end portion, the motion was much smaller (max.  $2a=0.3$  mm.) and rapidly decreased. [N.S. Component.] The principal portion lasted  $3^m 55^s$ . The motion became conspicuously large first, 62 sec. after the earthquake commencement, when there took place a max. group ( $2a=2.5$  mm) of  $T=5.2$  sec., followed by another ( $2a=2.6$  mm.) of  $T=3.1$  sec. The maximum group at the end of the principal portion, which began  $3^m 37^s$  after the earthquake commencement, was composed of the vibrations of max.  $2a=0.8$  mm., and of  $T=5.2$  sec. [Vertical Component.] The motion which was small for the first 33 sec. remained active for the next  $3^m 20^s$  sec., being composed of the pendulum vibrations of  $T=4.7$  sec. and  $2a=1.6$  mm. The secondary maximum group ( $2a=0.5$  mm.) occurred about  $3^m 40^s$  after the earthquake commencement.

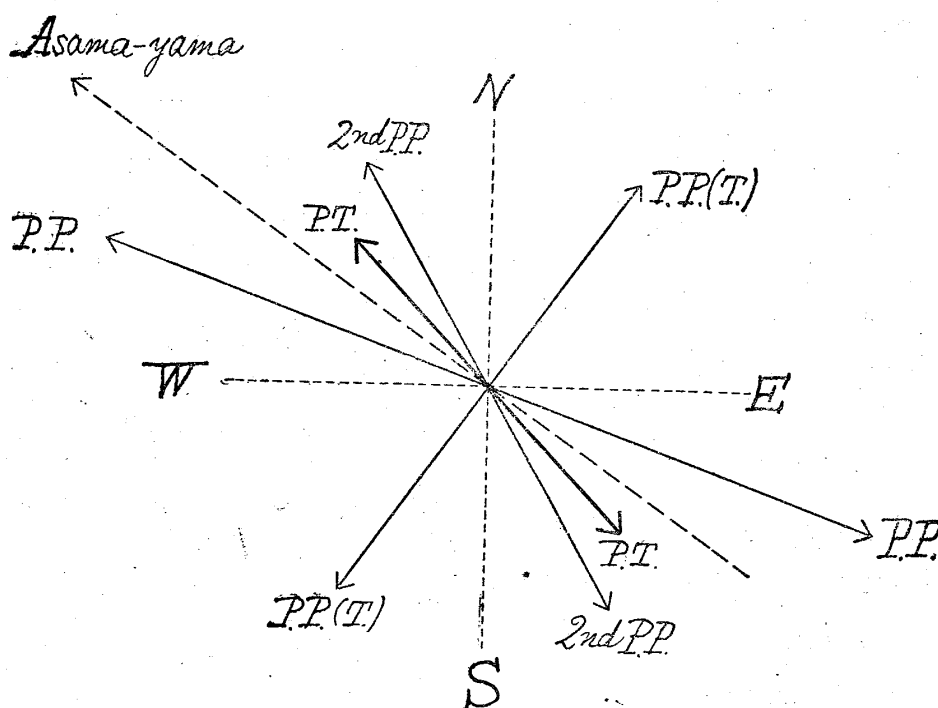
**86. (2) *Earthquake of July. 16th, 1912.*** Time of commencement=7.46.10 a.m. Duration of the preliminary tremor=18.3 sec. The very first displacement in the preliminary tremor was small

and directed toward the earthquake origin, the 2nd and the 3rd displacements being respectively  $2a=0.19$  mm. toward the  $E.32^{\circ}S.$  and  $2a=0.21$  mm. toward the  $W.35^{\circ}N.$  [E.W. Component.] The principal portion lasted  $4^m00^s$ . The motion was small during the first 21 sec., and consisted of the vibrations of  $T=6.0$  sec., max.  $2a=0.4$  mm. Then the motion became large and consisted of regular vibrations of  $T=7.1$  sec., of which the two maximum movements of  $2a=1.5$  mm. and  $2a=1.8$  mm. occurred respectively 47 and 71 sec. after the earthquake commencement; there being some mixtures of the quicker vibrations of  $2a=1.6$  mm.,  $T=2.6$  sec. The secondary maximum group at the end of the principal portion began  $3^m35.9$  after the earthquake commencement, and lasted 47.2 sec., being composed of 8 regular vibration of  $T=5.9$  sec., max.  $2a=1.4$  mm. In the end portion, the motion (max.  $2a=0.27$  mm.) rapidly decreased, and the average period was as follows:  $T=4.7$  sec.; 6.8 sec.; 7.3 sec.; 5.5 sec., etc.; there being also some traces of quick movements of  $T=2.8$  sec. [N.S. Component.] Preliminary tremor which lasted 19.0 sec., was composed of minute vibrations of  $T=1.2$  sec. mixed with slow movements of  $T=6.7$  sec.,  $2a=0.1$  mm. The principal portion, which lasted  $3^m57^s$ , was small during the first 44 sec. It attained the max.  $2a$  of 2.6 mm.  $1^m30^s$  after the earthquake commencement. The secondary maximum group at the end of the principal portion was composed of the vibrations of  $T=5.5$  sec.,  $2a=0.9$  mm.

The record from a *Pantograph*, or a large duplex pendulum instrument registering the resultant horizontal earthquake motion on a continuously moving smoked paper, was as follows:—The preliminary tremor lasted about 18.1 sec. and was composed of 6 small vibrations of  $T=3$  sec., executed approximately in the mean direction of  $S.43^{\circ}E.$  and  $N.43^{\circ}W.$  The principal portion began with slow

large vibrations (A), of  $2a=6.7$  mm., executed in the direction of S.  $70^\circ$  E. and N.  $70^\circ$  W. These were succeeded by well-defined vibrations (B), of  $2a=4.1$  mm, which began about 62 sec. after the earthquake commencement and had the mean direction of S.  $35^\circ$  W. and N.  $35^\circ$  E. These two maximum groups together occupied about  $2\frac{1}{2}$  min. Thereafter the motion became small till  $3\frac{1}{2}$  m. after the earthquake commencement, when there took place a secondary conspicuous maximum group (C) which lasted about 50 sec. and was composed of the vibrations ( $2a=4.1$  mm) executed in the direction of S.  $30^\circ$  E. and N.  $30^\circ$  W. Thereafter the motion became very small. (See fig. 36.)

Fig. 35. Diagram showing the Directions of Motion in the Different Portions of the Tokyo Seismograms of the Strong Asama-yama Earthquake on July 16th, 1912.



- P.T..... Preliminary Tremor.  
 P.P..... Principal Portion (earlier part).  
 2nd P.P..... Later Secondary Maximum.  
 P.P.(T) ... Principal Portion (Transverse Wave).

From the annexed diagram (fig. 35) it will be seen that the preliminary tremor, the large vibrations (A) at the commencement of the principal portion, and the prominent secondary maximum group (C) all belonged to the category of the longitudinal wave, while the group (B) which succeeded the principal maximum (A) was transverse in nature.

**87. (i) Earthquake of Jan. 22nd, 1899.** Time of commencement=8.04.03 a.m. Total duration=13 min. The commencement was not quite clear, on account of the presence of pulsatory oscillations; the preliminary tremor, which lasted about 27 sec., consisting of quick vibrations of  $T=0.84$  sec., mixed with slight traces of slower movements of  $T=6.5$  sec. The max.  $2a$  was 0.14 mm. in the E.W. and 0.1 mm. in the N.S. component. [Principal portion.] Duration= $4\frac{1}{2}$  m. The motion was specially active during the 1st  $1\frac{3}{4}$  m., consisting of small quick vibrations mixed with waves of  $T=2.3$  sec., and of max.  $2a=0.55$  mm. and 0.5 mm. respectively in the E.W. and N.S. components. These latter movements were in their turn again mixed with the slow movements of  $T=11.7$  sec., whose max.  $2a$  was 0.55 mm. in the E.W. and 0.6 mm. in the N.S. component. Towards the end, the period was 6.9 sec., there being a slight maximum ( $2a=0.23$  mm.) at  $4^m 39^s$  after the earthquake commencement. [End portion.] The prevailing period was 8.0 sec.\*

*Pulsatory oscillations.* The small pulsatory oscillations, which existed on the 21st and in the early morning of the 22nd, almost disappeared before the occurrence of the earthquake; the period being as follows:—

On the 21st, afternoon .....	3.9 sec.
Immediately before the earthquake .....	4.2 sec.

\* This account is materially the same as that given in the Publications, No. 6.

88. (3) *Earthquake of Jan. 22nd, 1910.* Time of commencement=3.3.46 p.m. This was a fairly large earthquake, although the area of sensible motion was limited in extension (§ 99). Total duration=17 min. [N.S. Component.] The preliminary tremor lasted 18.6 sec. and began with small motion, followed by two vibrations of  $T=7.0$  sec.,  $2a=0.07$  mm. In the principal portion, whose duration was 2m 35s, the motion was comparatively small for the first 44.2 sec.:  $2a=0.36$  mm.,  $T=6.8$  sec. Then the motion was most active for 27.3 sec., being composed of 5 vibrations of  $T=5.5$  sec., max.  $2a=1.2$  mm. (2nd vibration). Thereafter the motion became smaller, but a secondary maximum group forming the end of the principal portion occurred 118 sec. after the earthquake commencement. This lasted 56 sec. and was composed of the vibrations of  $T=4.0$  sec.,  $2a=0.65$  mm. In the end portion, the motion was much smaller (max.  $2a=0.17$  mm.), there being two series of movements of  $T=3.9$  sec., and  $T=7.6$  sec. [E.W. Component.] The motion began gradually, and the preliminary tremor and the principal portion lasted together 5m 02s. The motion which was small ( $2a=0.09$  mm.) for the first 32.2 sec., was most active for the next 2m 19s and the two greatest displacements of 0.81 and 0.87 mm. occurred respectively 47.4 and 109.0 sec. after the earthquake commencement;  $T=5.1$  sec.,  $T=9.1$  sec. A secondary maximum group, of  $T=5.0$  sec., and  $2a=0.44$  mm., occurred 3m 34s after the earthquake commencement. In the end portion,  $T=5.2$  sec., max.  $2a=0.11$  mm.

89. (4) *Earthquake of April 2nd, 1911.* Time of commencement=10.30.11 p.m. Total duration=6 m. The preliminary tremor lasted 18.0 sec., consisting of minute vibrations of  $T=0.37$  sec. apprx., mixed with other slower ones of max.  $2a=0.0051$  mm. [Principal Portion.] During the 1st 36.5 sec., the motion consisted

of quick movements of  $T=0.39$  sec., max.  $2a=0.012$  mm., mixed with well defined vibrations of  $T=1.9$  sec., max.  $2a=0.020$  mm.; there being also a trace of the superposition of slow oscillations of  $T=4.5$  sec. During the next 84.5 sec., the motion was largest and composed of the slow oscillations of  $T=4.5$  sec., max.  $2a=0.049$  mm., mixed with small movements of  $T=1.9$  sec., max.  $2a=0.013$  mm. During the next 41.4 sec., the motion was smaller, being chiefly composed of the vibrations of  $T=2.1$  sec. For the next 45.6 sec., the average period was 3.7 sec., the max.  $2a$  being 0.026 mm. Then followed 7 regular vibrations of decreasing magnitude and of  $T=4.5$  sec., which lasted together 31.5 sec., and the 1st of which had the max.  $2a$  of 0.036 mm. For the remaining  $1\frac{1}{2}$  min. the vibrations were small and mixed with the pulsatory oscillations.

The pulsatory oscillations, which existed about the time of the earthquake, were regular:  $T=4.5$  sec., max.  $2a=0.006$  mm. The period of the superposed micro-tremors was 0.59 sec.

90. (5) *Ueda earthquake of Aug. 17th, 1912.* Time of commencement= $11.21.53$  p.m.

*E. W. component tremor-recorder diagram, (magnification=300).*  
 [Preliminary tremor.] Duration= $21.9$  sec. The motion consisted of regular minute vibrations of  $T=0.29$  sec.,  $2a=0.003$  mm.  
 [Principal portion.] The motion began with a displacement of 0.018 mm. toward E. and consisted for the first 32.5 sec. of irregular vibrations of  $T=2.3$  sec. approx.,  $2a=0.036$  mm., more or less distinctly grouped into slower ones of  $T=9.3$  sec.,  $2a=0.065$  mm.; there being also superposition of quick movements. For the next 20.9 sec., there were 4 large pendulum oscillations of  $T=5.2$  sec., of which the 2nd had the max.  $2a$  of 0.32 mm. During the next 48 sec., there were slow irregular movements of  $T=8$  sec.,

# Tokyo Pantograph Observation.

Fig. 36. Strong Asama-yama Earthquake on July 16th, 1912. (Magnification = 20.)

(x) Commencement.

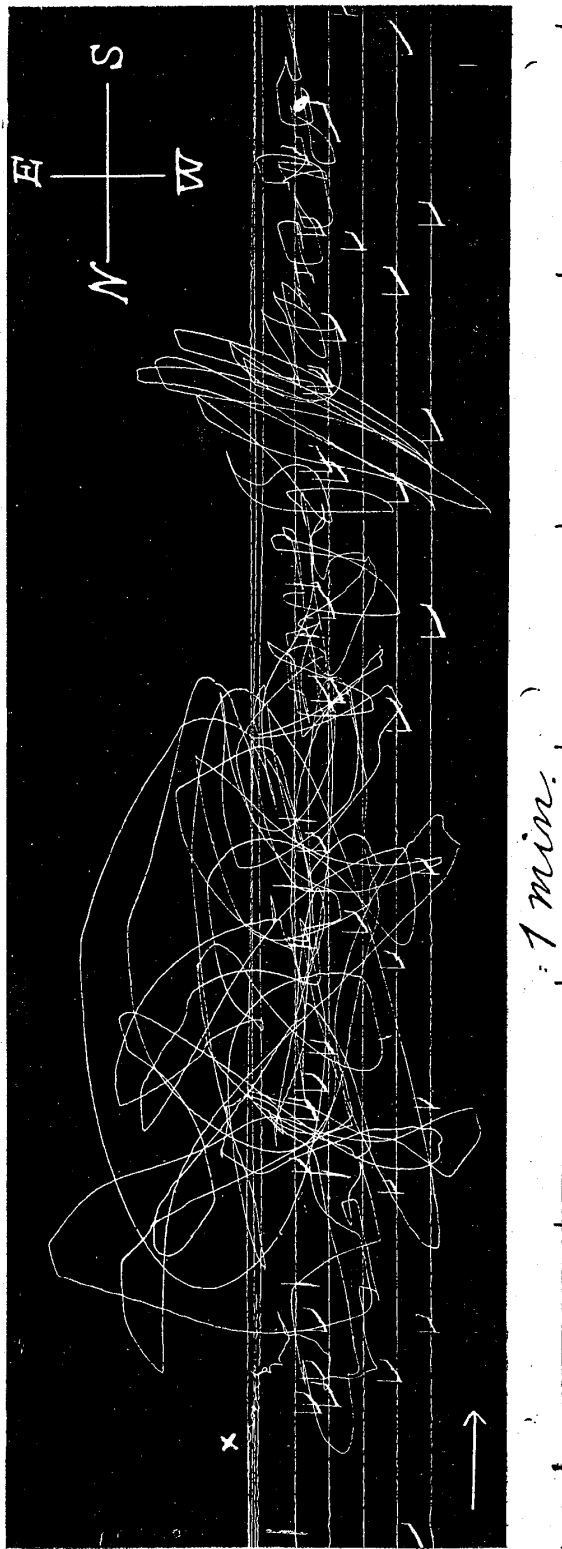
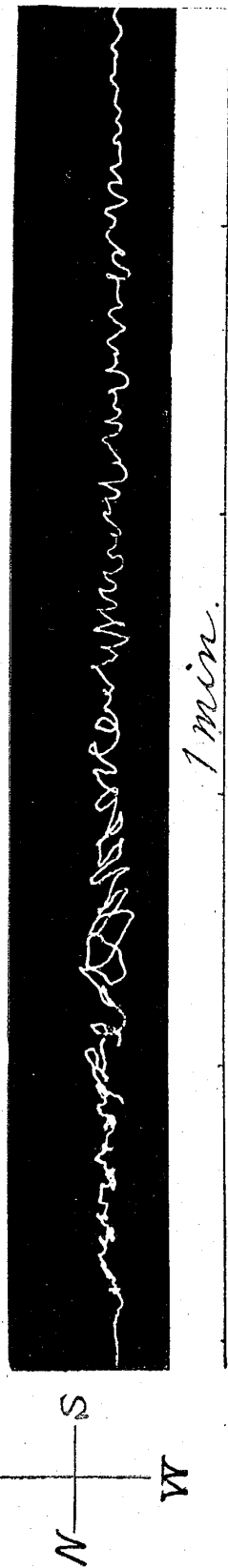


Fig. 37. Strong Nagaoka (Echigo) Earthquake on Aug. 29th, 1917. (Magnification = 35.)





Tokyo Observation of Strong Asama-yama Earthquakes.

Fig. 38. Strong Earthquake on May 26th, 1908. (Magnification=10.)

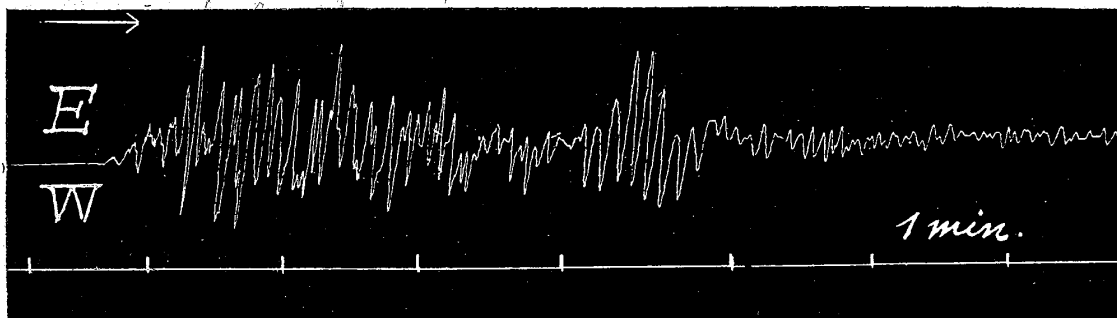


Fig. 39 Strong Earthquake on July 16th, 1912. (Magnification=10.)

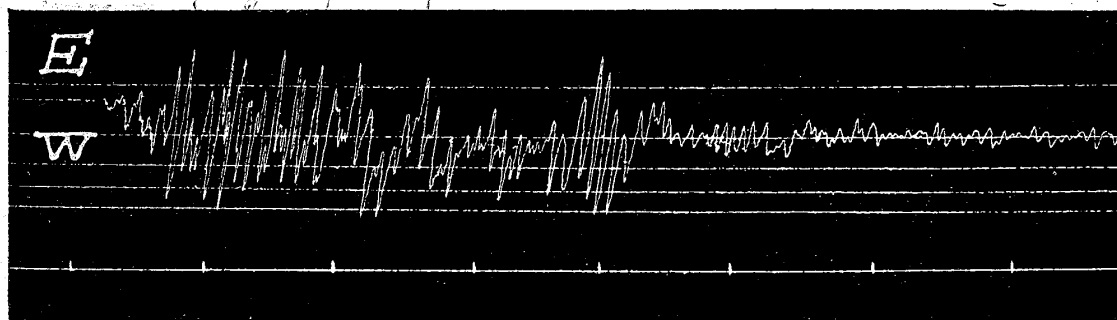


Fig. 40. Same Earthquake. (Magnification=15.)

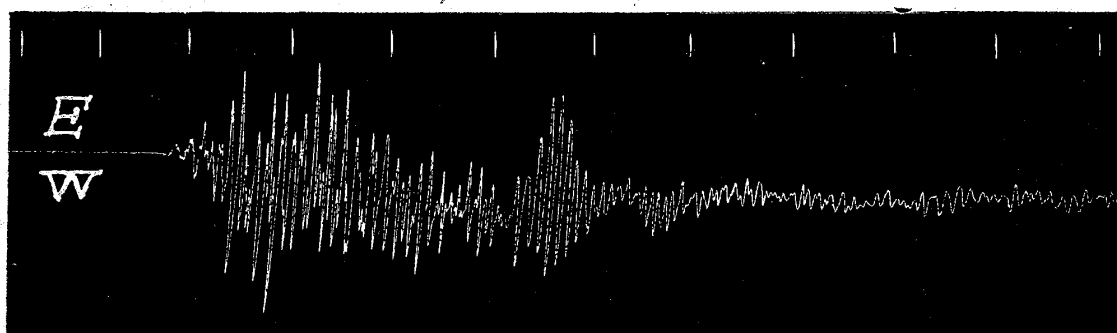


Fig. 41. Same Earthquake: Vertical Motion. (Magnification=10.)

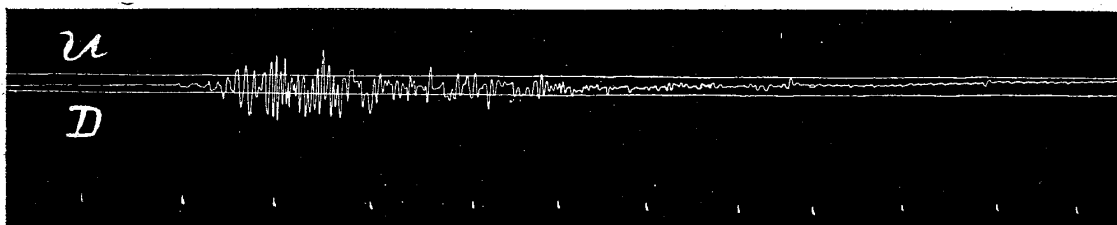
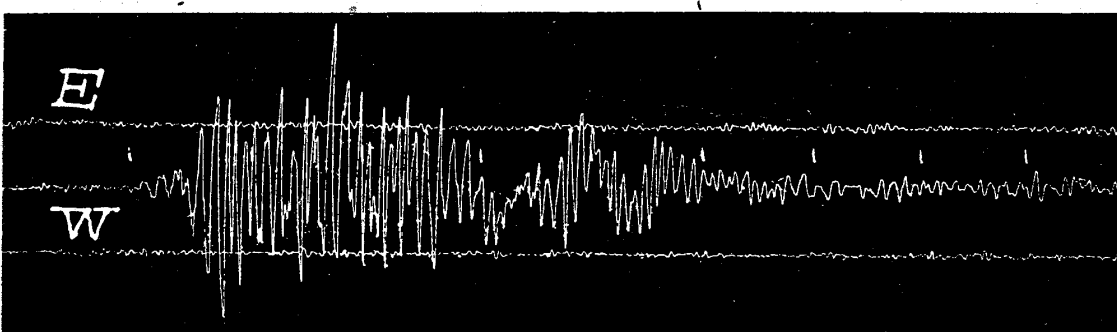


Fig. 42. Strong Earthquake on Jan. 22nd. 1910. (Magnification=30.)



$2a=0.09$  mm. During the next  $2^m 22^s$ , the motion consisted of vibrations of  $T=4.6$  sec.,  $2a=0.065$  mm., mixed with those of  $T=2.2$  sec. [End portion.] The motion was small:  $T=3.4$  sec.,  $2a=0.007$  mm.;  $T=5.1$  sec.,  $2a=0.013$  mm.

*E.W. component horizontal tromometer, (magnification=120).* Duration of the preliminary tremor= $21.5$  sec. During the 1st  $23.6$  sec. of the principal portion the motion was comparatively small. During the next  $25.1$  sec., the motion was most active:  $2a=0.19$  mm. (2nd vibration),  $T=5.6$  sec. Thereafter, the motion was smaller, and consisted, for the next  $73$  sec., of the vibrations of  $T=6.7$  sec.,  $2a=0.08$  mm., mixed with quicker movements. Thereafter the motion became much simpler, and, for the remaining  $2^m 34^s$ , had the  $T=5.2$  sec.,  $2a=1.3$  mm. In the end portion, the motion was small:  $2a=0.015$  mm.,  $T=4.8$  sec., mixed with the quick ones of  $T=3.1$  sec. It may be added that a single conspicuous maximum vibration ( $2a=0.08$  mm.) took place  $3^m 54^s$  after the commencement of the earthquake.

The very small pulsatory oscillations occurring about the time of the earthquake had, amongst the other, a period of  $4.1$  sec.

*N.S. component horizontal pendulum, (magnification=20).* The principal portion began with 3 irregular slow oscillations of  $T=11.5$  sec., lasting together  $34.4$  sec., followed for the next  $34.4$  sec., by 5 regular movements of  $T=6.9$  sec., max.  $2a=0.16$  mm. (3rd vibration). Thereafter the motion became smaller, the principal period being  $T=3.6$  sec.

**91. Period of earthquake vibration.** In the following table the periods of vibration in Tokyo of the non-eruptive Asama-yama earthquakes considered in the preceding §§ are compared with those of the motion due to the strong eruptions and ordinary earthquakes observed in the previous years in Tokyo and at the

Asama-yama observing stations. The various periods are found to exist more or less prominently at the different places of observation irrespective of the causes of disturbance. The mean values of the most frequently occurring movements are as follows:— 5.7 sec.; 2.55 sec.; 1.23 sec.; 0.85 sec.; and 0.36 sec. (See p.p. 154–156 of this volume.)

TABLE XXVI. PERIOD OF VIBRATION.

(A figure within brackets denotes the number of the observations from which the mean value has been deduced.)

Observation in Tokyo.				Observation at Asama-yama.						Mean.
Strong Non Eruptive Asama-yama Earthquakes.		Strong Asama-yama Eruptions.		Strong Explosions, and Non-Explosive Eruptions; small Eruptions; Volcanic Tremors.*		Ordinary Earthquakes, observed at Yuno-taira.		Ordinary Earthquakes observed at Asama Pasture Ground.		
T	2a	T	2a	T	2a	T	2a	T	2a	T
sec. 0.35(3)	mm 0.012			sec. 0.37 (83)	mm 0.053	sec. 0.33 (5)	mm 0.025	sec. 0.28 (8)	mm 0.048	sec. 0.36
0.84(1)				0.85(104)	0.083	0.95(12)	0.32	0.76(14)	0.031	0.85
1.20 (1)				1.23(148)	0.130					1.23
2.46(10)	1.60	3.0(31)	0.031	2.3 (27)	0.122	2.2 (18)	0.043			2.55
5.80(31)	2.50	5.5(18)	0.028	4.9 (13)	0.21	6.0 (6)	0.051	5.4 (4)	—	5.70
10.5 (2)	0.55									10.5
						26.4 (1)	—			26.4

\* Observed at Yuno-taira, Ashino-taira, and Asama Pasture Ground.